

IN THE MATTER OF two  
German Patent Applications  
in the name of  
Gesellschaft fuer Biotechnolog-  
ische Forschung mbH (GBF)  
filed under  
196 47 580.5 ~~and 197 07 506.1~~  
and  
IN THE MATTER OF an Application  
for Patent in Singapore

I, Dr. Hans D. Boeters, translator and patent attorney of  
BOETERS & BAUER, Bereiteranger 15, D-81541 Muenchen, Germany, do  
solemnly and sincerely declare that I am conversant with the  
English and German languages and am a competent translator  
thereof, and that the following is, to the best of my knowledge  
and belief, a true and correct translation of the patent  
applications filed under 196 47 580.5 ~~and 197 07 506.1~~

by Gesellschaft fuer Biotechnologische Forschung mbH (GBF)

before the German Patent Office on December 18, 1996 and  
February 2, 1997

for "~~Epothilon E and F~~" and "Epothilons C and D, preparations  
and compositions"

and the Official Certificates attached thereto.

Date: June 9, 1999

  
(Dr. Boeters)

**FEDERAL REPUBLIC OF GERMANY**  
**CERTIFICATE**

Gesellschaft für Biotechnologische Forschung mbH (GBF) of Braunschweig/Germany  
filed at the German Patent Office on 18th November, 1996 a Patent Application  
entitled

"Epothilons C and D, preparation and compositions".

The attached documents are a correct and accurate reproduction of the original  
supporting documents of this Patent Application.

The Application has provisionally been given in the German Patent Office the symbols  
C 07 D, C 07 F and A 01 N of the International Patent Classification.

Seal of the German  
Patent Office

Munich, 18th December 1997  
The President of the German  
Patent Office  
By order

(signature)

File reference: 196 47 580.5

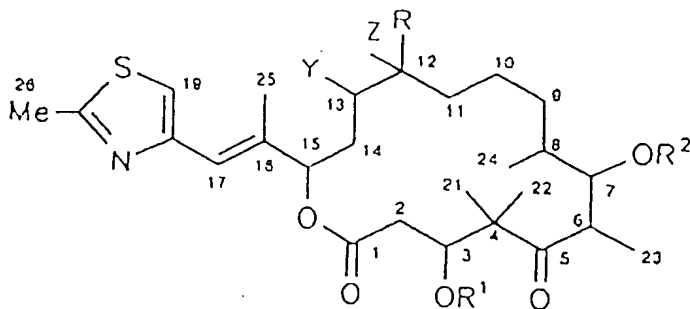
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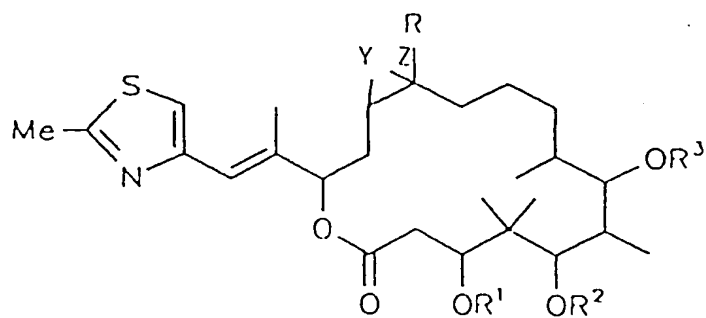
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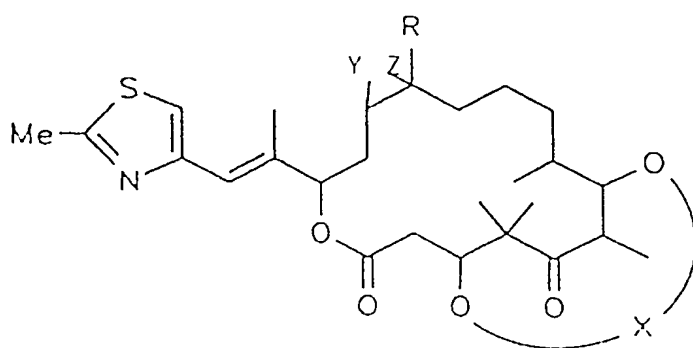
### Epothilons C and D, preparation and compositions

The present invention relates generally to epothilon derivatives and to their use in the preparation of medicaments. The present invention relates especially to the preparation of epothilon derivatives of general formulae 1 to 7 shown hereinafter and to their use in the preparation of therapeutic compositions and compositions for plant protection.

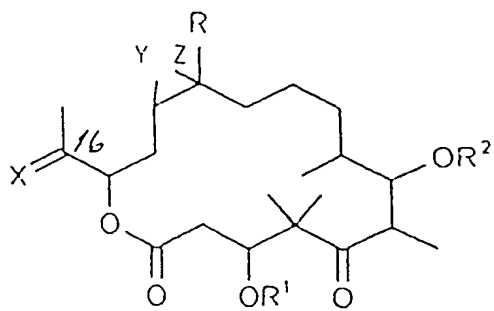




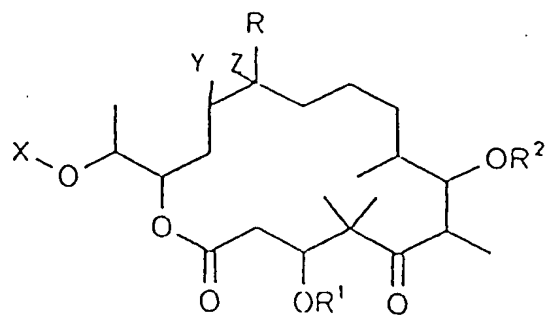
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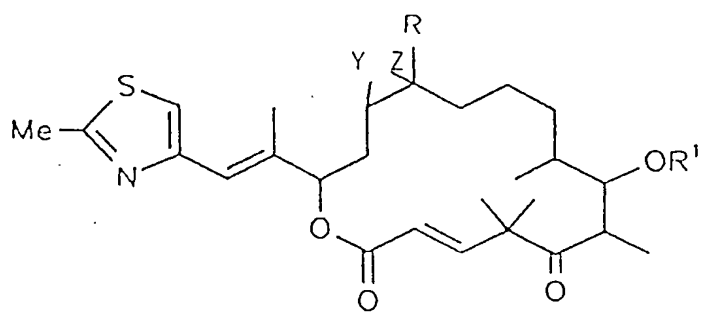
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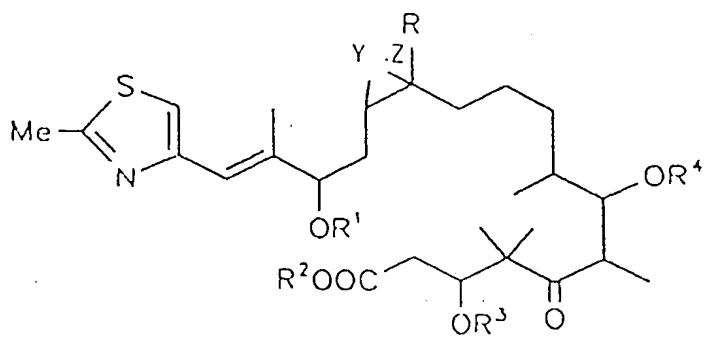
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6



7

In formulae 1 to 7 given above:

R = H, C<sub>1-4</sub>alkyl;

R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup> = H, C<sub>1-6</sub>alkyl,  
C<sub>1-6</sub>acyl-benzoyl,  
C<sub>1-4</sub>trialkylsilyl,  
benzyl,  
phenyl,  
benzyl or phenyl each substituted by C<sub>1-6</sub>alkoxy,  
C<sub>6</sub>alkyl, hydroxy or by halogen;

it also being possible for two of the radicals R<sup>1</sup> to R<sup>5</sup> to occur together to form a group -(CH<sub>2</sub>)<sub>n</sub>- wherein n is from 1 to 6, and the alkyl and acyl groups contained in the radicals are straight-chain or branched radicals;

Y and Z are either identical or different and each represents hydrogen, halogen, such as F, Cl, Br or I, pseudohalogen, such as -NCO, -NCS or -N<sub>3</sub>, OH, O-(C<sub>1-6</sub>)acyl, O-(C<sub>1-6</sub>)alkyl, O-benzoyl. Y and Z may also be the O atom of an epoxy group, epothilon A and B not being claimed, or one of the C-C bonds of a C=C double bond.

In formula 3, X generally represents -C(O)-, -C(S)-, -S(O)-, -CR<sup>1</sup>R<sup>2</sup>-, wherein R<sup>1</sup> and R<sup>2</sup> are as defined above, or -SiR<sub>2</sub>- wherein R is as defined above.

In formula 4, X represents oxygen, NOR<sup>3</sup>, N-NR<sup>4</sup>R<sup>5</sup> or N-NHCONR<sup>4</sup>R<sup>5</sup>, wherein the radicals R<sup>3</sup> to R<sup>5</sup> are as defined above.

In formula 5, X represents hydrogen, C<sub>1-18</sub>alkyl, C<sub>1-18</sub>acyl, benzyl, benzoyl or cinnamoyl.

For epothilons A and B, see DE-A-41 38 042.

Compounds according to general formula 1 can be obtained starting from epothilon A and B and from their 3-O- and/or 7-O-protected derivatives by opening the 12,13-epoxy group. If hydrohalic acids are used for that purpose in a preferably non-aqueous solvent, there being obtained the halohydrins X = Hal, Y = OH and Y = OH, Y = Hal. Protonic acids, such as, for example, toluenesulphonic acid and

trifluoroacetic acid, result, in the presence of water, in 12,13-diols which are then acylated (e.g. with carboxylic acid anhydrides and pyridine or triethylamine/DMAP) or alkylated (alkylhalides and silver oxide) according to standard processes. For that purpose, the 3- and 7-hydroxy groups may be protected temporarily in the form of a formate (removal with  $\text{NH}_3/\text{MeOH}$ ) or of a p-methoxybenzyl ether (removal with DDQ).

Compounds according to general formula 2 are obtainable from epothilon A and B and also from their 3-O- and/or 7-O-protected derivatives by reduction, for example with  $\text{NaBH}_4$  in methanol. If 3-OH and/or 7-OH are protected reversibly, then after acylation or alkylation and removal of the protecting groups there may be obtained 5-O-monosubstituted or 3,5- or 5,7-O-disubstituted derivatives of general formula 2.

Reactions of epothilon A and B with bifunctional electrophilic reagents, such as (thio)phosgene, (thio)carbonyldiimidazole, thionyl chloride or dialkylsilyl dichlorides or bistriflates yield compounds of general formula 3. Pyridine, trialkylamines, optionally together with DMAP or 2,6-lutidine in an aprotic solvent serve as auxiliary bases in the process. The 3,7-acetals of general formula 3 are produced by transacetalisation, for example of dimethylacetals in the presence of an acid catalyst.

Compounds according to general formula 4 are obtained from epothilon A and B or from 3-O- and/or 7-O-protected derivatives thereof by ozonolysis and reductive working up, for example with dimethyl sulphide. The C-16-ketones may then be converted into oximes, hydrazones or semicarbazones in accordance with standard processes known to the person skilled in the art. They are, moreover, converted into C-16-/C-17-olefins by Wittig, Wittig-Horner, Julia or Petersen olefination.

The 16-hydroxy derivatives according to general formula 5 are obtainable by reduction of the C-16-keto group, for example with an aluminium hydride or borohydride. If 3-OH and 7-OH are provided with suitable protecting groups, the 16-hydroxy derivatives may be either acylated or alkylated. The 3-OH and 7-OH groups are freed, for example, in the case of O-formyl by  $\text{NH}_3/\text{MeOH}$  and, in the case of O-p-methoxybenzyl, by DDQ.

The compounds of general formula 6 are obtained from derivatives of epothilon A and B, in which the 7-OH group has been protected by acyl or ether groups, by, for example, formylating, mesylating or tosylating the 3-OH group and then eliminating it by treatment with a base, for example DBU. The 7-OH group can be freed as described above.

Compounds of general formula 7 are obtained from epothilon A and B or from 3-OH- and 7-OH-protected derivatives thereof by basic hydrolysis, for example with NaOH in MeOH or MeOH/water. Preferably compounds of general formula 7 are obtained from epothilon A or B or from 3-OH- or 7-OH-protected derivatives thereof by enzymatic hydrolysis, especially with esterases or lipases. The carboxy group can be converted to an ester with a diazoalkane after protection of the 19-OH group by alkylation.

Moreover, compounds of formula 7 may be converted into compounds of formula 2 by lactonisation in accordance with the methods of Yamaguchi (trichlorobenzoyl chloride/DMAP), Corey (aldrithiol/triphenylphosphine) or Kellogg (omega-bromic acid/caesium carbonate). Relevant working methods may be found in Inanaga *et al.* in Bull. Chem. Soc. Japan, 52 (1979) 1989; Corey & Nicolaou in J. Am. Chem. Soc., 96 (1974) 5614; and Kruizinga & Kellogg in J. Am. Chem. Soc., 103 (1981) 5183.

To prepare the compounds according to the invention, it is also possible to start from epothilon C or D, where, for the derivatisation, reference may be made to the derivatisation methods described above. The 12,13-double bond may be hydrogenated, for example catalytically or with diimine; or epoxidised, for example with dimethyldioxirane or with a peracid; or converted into a dihalide, dipseudohalide or diazide.

The invention relates also to compositions for plant protection in agriculture, forestry and/or horticulture, consisting of one or more of the above-mentioned epothilon derivatives or consisting of one or more of the above-mentioned epothilon derivatives together with one or more customary carrier(s) and/or diluent(s).



Finally, the invention relates to therapeutic compositions consisting of one or more of the above-mentioned compounds or of one or more of the above-mentioned compounds together with one or more customary carrier(s) and/or diluent(s). Those compositions may especially demonstrate cytotoxic activities and/or cause immunosuppression and/or be used to combat malignant tumours; they are especially preferably usable as cytostatic agents.

The invention is illustrated and described hereinafter in greater detail by the description of a number of selected embodiments.

### Examples

#### Example 1:

##### Compound 1a

20 mg (0.041 mmol) of epothilon A are dissolved in 1 ml of acetone, 50  $\mu$ l (0.649 mmol) of trifluoroacetic acid are added and the reaction mixture is stirred overnight at 50°C. The reaction mixture is worked up by adding 1M phosphate buffer pH 7 and extracting the aqueous phase four times with ethyl acetate. The combined organic phases are washed with saturated sodium chloride solution, dried over sodium sulphate and freed of solvent. The crude product is purified by preparative layer chromatography (eluant: dichloromethane/acetone, 85:15).

Yield: 4 mg (19%) of isomer I  
4 mg (19%) of isomer II

##### Isomer I

$R_f$  (dichloromethane/acetone, 85:15) : 0.46

IR (film):  $\nu_{\text{max}}$  = 3440 (m, b, sh), 2946 (s, sh), 1734 (vs), 1686 (m),  
1456 (m), 1375 (w), 1256 (s, sh), 1190 (w, b, sh),  
1071 (m, sh), 884 (w), 735 (w)  $\text{cm}^{-1}$ .

MS (20/70 eV) : m/e (%) = 493 (43 [M-H<sub>2</sub>O]<sup>+</sup>), 394 (47), 306 (32), 206 (30),  
181 (40), 166 (72), 139 (100), 113 (19), 71 (19),  
57 (24), 43 (24).

Microanalysis: C<sub>26</sub>H<sub>39</sub>O<sub>6</sub>NS calc.: 493.2498 for [M-H<sub>2</sub>O]<sup>+</sup>  
found: 493.2478

#### Isomer II

R<sub>f</sub> (dichloromethane/acetone, 85:15) : 0.22

IR (film) :      ny = 3484 (s, b, sh), 2942 (vs, sh), 1727 (vs), 1570 (w),  
1456 (m), 1380 (m), 1265 (s), 1190 (w), 1069 (m),  
975 (w) cm<sup>-1</sup>.

MS (20/70 eV) : m/e (%) = 493 (21 [M-H<sub>2</sub>O]<sup>+</sup>), 394 (12), 306 (46), 206 (37),  
181 (63), 166 (99), 139 (100), 113 (21), 71 (23),  
57 (33), 43 (28).

Microanalysis: C<sub>25</sub>H<sub>39</sub>O<sub>6</sub>NS calc. : 493.2498 for [M-H<sub>2</sub>O]<sup>+</sup>  
found: 493.2475

#### Example 2:

##### Compound 1b

55 mg (0.111 mmol) of epothilon A are dissolved in 0.5 ml of tetrahydrofuran, 0.5 ml of 1N hydrochloric acid is added, and the reaction mixture is stirred at room temperature for 30 minutes. 1N Phosphate buffer pH 7 is then added and the aqueous phase is extracted four times with ethyl acetate. The combined organic phases are washed with saturated sodium chloride solution, dried over sodium sulphate and freed of solvent. The crude product is purified by preparative layer chromatography (eluant: dichloromethane/methanol, 90:10). Yield: 19 mg (32%).

R<sub>f</sub> (dichloromethane/methanol, 90:10) : 0.46

IR (film) :  $\nu$  = 3441 (s, br, sh), 2948 (s, sh), 1725 (vs, sh), 1462 (m),  
1381 (w), 1265 (m), 1154 (w), 972 (m, br, sh)  $\text{cm}^{-1}$ .

UV (methanol) :  $\lambda_{\text{max}}$  (lg epsilon) = 210 (4.29), 248 (4.11) nm.

MS (20/70 eV) : m/e (%) = 529 (13 [ $\text{M}^+$ ]), 494 (10), 342 (38), 306 (23),  
194 (32), 164 (100), 140 (31), 113 (15), 57 (16).

Microanalysis:  $\text{C}_{26}\text{H}_{40}\text{O}_6\text{ClNS}$  calc.: 529.2265 for [ $\text{M}^+$ ],  
found: 529.2280

### Example 3:

#### Compound 1c

25 mg (0.047 mmol) of 12-chloro-13-hydroxy-epothilon A (**1b**) are dissolved in 1 ml of dichloromethane, and 29 mg (0.235 mmol) of dimethylaminopyridine, 151  $\mu\text{l}$  (1.081 mmol) of triethylamine and 20  $\mu\text{l}$  (0.517 mmol) of 98% formic acid are added. The reaction mixture is cooled with ice/salt. When  $-15^\circ\text{C}$  has been reached, 40  $\mu\text{l}$  (0.423 mmol) of acetic anhydride are added to the reaction mixture, which is stirred for 70 minutes at  $-15^\circ\text{C}$ . Since thin-layer chromatography shows that the reaction is not complete, a further 6 mg (0.047 mmol) of dimethylaminopyridine, 7  $\mu\text{l}$  (0.047 mmol) of triethylamine, 2  $\mu\text{l}$  of 98% formic acid (0.047 mmol) and 4  $\mu\text{l}$  (0.047 mmol) of acetic anhydride are added to the reaction mixture, which is stirred for 60 minutes. The reaction mixture is worked up by heating to room temperature, adding 1M phosphate buffer pH 7 and extracting the aqueous phase four times with ethyl acetate. The combined organic phases are washed with saturated sodium chloride solution, dried over sodium sulphate and freed of solvent. The crude product is purified by preparative layer chromatography (eluant: dichloromethane/acetone, 90:10). Yield: 5 mg (18%).

R<sub>f</sub> (dichloromethane/acetone, 90:10) : 0.67

IR (film) :      ny =    3497 (w, b, sh), 2940 (s, b, sh), 1725 (vs), 1468  
                        (m, b, sh), 1379 (m), 1265 (s), 1253 (s), 1175 (vs), 972  
                        (m, b, sh), 737 (s) cm<sup>-1</sup>.

MS (20/70 eV) : m/e (%) = 613 (9 [M<sup>+</sup>]), 567 (43), 472 (63), 382 (23), 352 (21),  
164 (100), 151 (33), 96 (31), 69 (17), 44 (26).

Microanalysis: C<sub>29</sub>H<sub>40</sub>O<sub>9</sub>NSCl      calc.: 613.2112 for [M<sup>+</sup>]  
found: 613.2131

### Example 4:

### Compound 1d

10 mg (0.020 mmol) of epothilon B are dissolved in 0.5 ml of tetrahydrofuran, 0.5 ml of 1N hydrochloric acid is added and the reaction mixture is stirred at room temperature for 30 minutes. 1M Phosphate buffer pH 7 is then added and the aqueous phase is extracted four times with ethyl acetate. The combined organic phases are washed with saturated sodium chloride solution, dried over sodium sulphate and freed of solvent. The crude product is purified by preparative layer chromatography (eluant: dichloromethane/acetone, 85:15).  
Yield: 1 mg (9%).

R<sub>f</sub> (dichloromethane/acetone, 85:15) : 0.38

MS (20/70 eV) : m/e (%) = 543 (3 [M<sup>+</sup>]), 507 (14), 320 (19), 234 (9), 194 (17),  
182 (23), 164 (100), 140 (22), 113 (14), 71 (13).

Microanalysis: C<sub>27</sub>H<sub>42</sub>O<sub>6</sub>NSCl      calc.: 543.2421 for [M<sup>+</sup>]  
found: 543.2405

**Example 5:**

**Compound 2a**

100 mg (0.203 mmol) of epothilon A are dissolved in 4 ml of tetrahydrofuran/-1M phosphate buffer pH 7 (1:1), and sodium borohydride (150 mg = 3.965 mmol) is added until the starting material has reacted completely according to thin-layer chromatography. Dilution with 1M phosphate buffer pH 7 is then carried out and the aqueous phase is extracted four times with ethyl acetate. The combined organic phases are washed with saturated sodium chloride solution, dried over sodium sulphate and freed of solvent. The crude product is purified by silica chromatography (eluant: dichloromethane/acetone, 95:5 - gradient - to dichloromethane/acetone, 85:15).

Yield: (20%)

R<sub>f</sub> (dichloromethane/acetone, 75:25) : 0.27

IR (film) :      ny =    3413 (s, b, sh), 2965 (vs, sh), 1734 (vs), 1458 (m, b, sh),  
                         1383 (m, sh), 1264 (s, b, sh), 1184 (m, b, sh), 1059  
                         (s, sh), 966 (s), 885 (w), 737 (m) cm<sup>-1</sup>.

MS (20/70 eV) : m/e (%) =    495 (6 [M<sup>+</sup>]), 477 (8), 452 (12), 394 (9), 364 (16),  
   306 (49), 194 (19), 178 (35), 164 (100), 140 (40), 83  
   (21), 55 (27).

Microanalysis : C<sub>26</sub>H<sub>41</sub>O<sub>6</sub>NS    calc. : 495.2655 for [M<sup>+</sup>]  
   found: 495.2623

**Example 6:**

**Compound 3a-d (a-d are stereoisomers)**

100 mg (0.203 mmol) of epothilon are dissolved in 3 ml of pyridine, 50  $\mu$ l (0.686 mmol) of thionyl chloride are added and the reaction mixture is stirred at room temperature for 15 minutes. 1M Phosphate buffer pH 7 is then added and the aqueous phase is extracted four times with ethyl acetate. The combined organic phases are washed with saturated sodium chloride solution, dried over sodium sulphate and freed of solvent. The crude product is purified and the four stereoisomers 3a-d are separated by preparative layer chromatography (eluant: toluene/methanol, 90:10).

**Compound 3a**

Yield : 4 mg (12%)

R<sub>f</sub> (toluene/methanol, 90:10) : 0.50

IR (film) :  $\nu_{\text{max}}$  = 2961 (m, b, sh), 1742 (vs), 1701 (vs), 1465 (m, sh),  
1389 (m, sh), 1238 (s, sh), 1210 (vs, sh), 1011 (s, sh),  
957 (s, b, sh), 808 (m, sh), 768 (s, sh)  $\text{cm}^{-1}$ .

UV (methanol) :  $\lambda_{\text{max}}$  ( $\lg \epsilon$ ) = 210 (4.50), 248 (4.35) nm.

MS (20/70 eV) : m/e (%) = 539 (40 [ $\text{M}^+$ ]), 457 (22), 362 (16), 316 (27), 222 (30),  
178 (30), 164 (100), 151 (43), 96 (38), 69 (29), 55 (28),  
43 (20).

Microanalysis:  $\text{C}_{26}\text{H}_{37}\text{O}_7\text{NS}_2$  calc. : 539.2011 for [ $\text{M}^+$ ]

**Compound 3b**

Yield : 14 mg (13%)

R<sub>f</sub> (toluene/methanol, 90:10) : 0.44

IR (film) :  $\nu$  = 2963 (s, br, sh), 1740 (vs), 1703 (s), 1510 (w), 1464 (m, br, sh), 1389 (m, sh), 1240 (s, br, sh), 1142 (m), 1076 (w), 1037 (w), 1003 (m), 945 (s, br, sh), 806 (m, sh), 775 (s), 737 (m)  $\text{cm}^{-1}$ .

UV (methanol) :  $\lambda_{\text{max}}$  (lg epsilon) = 211 (4.16), 250 (4.08) nm.

MS (20/70 eV) : m/e (%) = 539 (27 [ $\text{M}^+$ ]), 475 (17), 322 (41), 306 (67), 222 (16), 206 (17), 194 (19), 178 (32), 164 (100), 151 (33), 125 (18), 113 (15), 96 (39), 81 (23), 64 (58), 57 (42), 41 (19).

Microanalysis :  $\text{C}_{26}\text{H}_{37}\text{O}_7\text{NS}_2$  calc. : 539.2011 for [ $\text{M}^+$ ]  
found: 539.1998

**Compound 3c**

Yield : 4 mg (4%)

R<sub>f</sub> (toluene/methanol, 90:10) : 0.38

MS (20/70 eV) : m/e (%) = 539 (51 [ $\text{M}^+$ ]), 322 (22), 306 (53), 222 (36), 178 (31), 164 (100), 151 (41), 96 (25), 81 (20), 69 (26), 55 (25), 41 (25).

Microanalysis :  $\text{C}_{26}\text{H}_{37}\text{O}_7\text{NS}_2$  calc. : 539.2011 for [ $\text{M}^+$ ]  
found: 539.2001

### Compound 3d

Yield : 1 mg (1%)

R<sub>f</sub> (toluene/methanol, 90:10) : 0.33

MS (20/70 eV) : m/e (%) = 539 (69 [M<sup>+</sup>]), 322 (35), 306 (51), 222 (41), 178 (31), 164 (100), 151 (46), 96 (31), 81 (26), 69 (34), 55 (33), 41 (35)

Microanalysis : C<sub>26</sub>H<sub>37</sub>O<sub>7</sub>NS<sub>2</sub>      calc. : 539.2011 for [M<sup>+</sup>]  
found: 539.1997

### Example 7

#### Compound 4a

10 mg (0.020 mmol) of epothilon A are dissolved in 2 ml of dichloromethane, cooled to -70°C and then treated with ozone for 5 minutes until there is a slight blue coloration. 0.5 ml of dimethyl sulphide is subsequently added to the resulting reaction mixture, which is heated to room temperature. The reaction mixture is worked up by freeing it of solvent and finally by preparative layer chromatography (eluant: dichloromethane/-acetone/methanol, 85:10:5).

Yield : 5 mg (64%)

R<sub>f</sub> (dichloromethane/acetone/methanol, 85:10:5) : 0.61

IR (film) :      ν<sub>y</sub> = 3468 (s, br, sh), 2947 (s, br, sh), 1734 (vs, sh), 1458 (w),  
1380 (w), 1267 (w), 1157 (w), 1080 (w), 982 (w) cm<sup>-1</sup>.

UV (methanol) : λ<sub>max</sub> (lg ε) = 202 (3.53) nm.



MS (20/70 eV) : m/e (%) = 398 (2 [M<sup>+</sup>]), 380 (4), 267 (14), 249 (17), 211 (20), 193 (26), 171 (34), 139 (34), 111 (40), 96 (100), 71 (48), 43 (50).

Microanalysis : C<sub>21</sub>H<sub>34</sub>O<sub>7</sub> : calc. : 398.2305 for [M<sup>+</sup>]  
found: 398.2295

#### Example 8:

##### Compound 6a

10 mg (0.018 mmol) of 3,7-di-O-formyl-epothilon A are dissolved in 1 ml of dichloromethane, 27  $\mu$ l (0.180 mmol) of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) are added and the reaction mixture is stirred at room temperature for 60 minutes.

The reaction mixture is worked up by adding 1M sodium dihydrogen phosphate buffer pH 4.5 and extracting the aqueous phase four times with ethyl acetate. The combined organic phases are washed with saturated sodium chloride solution, dried over sodium sulphate and freed of solvent. After the solvent has been removed, the resulting crude product is dissolved in 1 ml of methanol, 200  $\mu$ l of an ammoniacal methanol solution (2 mmol NH<sub>3</sub>/ml methanol) are added and the mixture is stirred overnight at room temperature. To work up, the solvent is removed *in vacuo*.

Yield : 4 mg (22%)

R<sub>f</sub> (dichloromethane/acetone, 85:15) : 0.46

IR (film) :  $\nu$  = 3445 (w, br, sh), 2950 (vs, br, sh), 1717 (vs, sh), 1644 (w), 1466 (m, sh), 1370 (m, sh), 1267 (s, br, sh), 1179 (s, sh), 984 (s, sh), 860 (w), 733 (m) cm<sup>-1</sup>.

UV (methanol) :  $\lambda_{\text{max}}$  (lg epsilon) = 210 (4.16) nm.

MS (20/70 eV) : m/e (%) = 475 (28 [M<sup>+</sup>]), 380 (21), 322 (37), 318 (40), 304 (66), 178 (31), 166 (100), 151 (29), 140 (19), 96 (38), 81 (20), 57 (26).

Microanalysis : C<sub>26</sub>H<sub>37</sub>O<sub>5</sub>NS      calc.: 475.2392 for [M<sup>+</sup>]  
found: 475.2384

**Example 9:**

**Compound 6b**

50 mg (0.091 mmol) of 3,7-di-O-formyl-epothilon A are dissolved in 1 ml of dichloroethane, 2 ml (0.013 mmol) of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) are added and the reaction mixture is stirred for 12 hours at 90°C.

The reaction mixture is worked up by adding 1M sodium dihydrogen phosphate buffer pH 4.5 and extracting the aqueous phase four times with ethyl acetate. The combined organic phases are washed with saturated sodium chloride solution, dried over sodium sulphate and freed of solvent. The crude product, consisting of two compounds, is purified by preparative layer chromatography (eluant: dichloromethane/acetone, 90:10).

Yield : 7 mg (15%)

Substance code

R<sub>f</sub> (dichloromethane/acetone, 90:10) : 0.62

IR (film) :      ny = 2951 (m, br, sh), 1723 (vs), 1644 (w, br, sh), 1468 (w), 1377 (w), 1271 (m, br, sh), 1179 (s), 987 (m, br, sh), 735 (w, br, sh) cm<sup>-1</sup>.

UV (methanol) : lambda<sub>max</sub> (lg epsilon) = 210 (4.44) nm.

MS (20/70 eV) : m/e (%) = 503 (68 [M<sup>+</sup>]), 408 (58), 390 (32), 334 (25), 316 (34), 220 (21), 206 (27), 194 (20), 181 (33), 164 (100), 151 (34), 139 (28), 113 (20), 96 (82), 81 (33), 67 (24), 55 (26), 43 (22).

Microanalysis : C<sub>27</sub>H<sub>37</sub>O<sub>6</sub>NS calc.: 503.2342 for [M<sup>+</sup>]  
found: 503.2303

### Example 10

#### Compound 6c

5 mg (0.009 mmol) of 3,7-di-O-acetyl-epothilon are dissolved in 1 ml of methanol, 150  $\mu$ l of an ammoniacal methanol solution (2 mmol NH<sub>3</sub>/ml methanol) are added and the reaction mixture is stirred overnight at 50°C.

To work up, the solvent is removed *in vacuo*. The crude product is purified by preparative layer chromatography (eluant: toluene/methanol, 90:10).

Yield : 3 mg (67%)

R<sub>f</sub> (dichloromethane/acetone, 90:10) : 0.55

IR (film) :  $\nu$  = 2934 (s, b, sh), 1719 (vs, b, sh), 1641 (m), 1460 (m, sh), 1372 (s, sh), 1237 (vs, b, sh), 1179 (s, sh), 1020 (s), 963 (s, sh), 737 (vs) cm<sup>-1</sup>.

UV (methanol) :  $\lambda_{\text{max}}$  (lg epsilon) = 210 (4.33) nm.

MS (20/70 eV) : m/e (%) = 517 (57 [M<sup>+</sup>]), 422 (58), 318 (31), 194 (20), 181 (34), 166 (100), 151 (31), 96 (96), 81 (32), 69 (27), 55 (29), 43 (69).

Microanalysis : C<sub>28</sub>H<sub>39</sub>O<sub>6</sub>NS calc.: 517.2498 for [M<sup>+</sup>]  
found: 517.2492

### Example 11

#### Compound 7a

20 mg (0.041 mmol) of epothilon are dissolved in 0.5 ml of methanol, 0.5 ml of 1N sodium hydroxide solution is added and the reaction mixture is stirred at room temperature for 5 minutes.

The reaction mixture is worked up by adding 1M phosphate buffer pH 7 and extracting the aqueous phase four times with ethyl acetate. The combined organic phases are washed with saturated sodium chloride solution, dried over sodium sulphate and freed of solvent. The crude product is purified by preparative layer chromatography (eluant: dichloromethane/methanol, 85:15).

Yield : 11 mg (52%)

R<sub>f</sub> (dichloromethane/methanol, 85:15) : 0.92

IR (film) :       $\nu$  = 3438 (s, br, sh), 2971 (vs, br, sh), 1703 (vs), 1507 (m),  
1460 (s, sh), 1383 (m, sh), 1254 (w), 1190 (w, br, sh),  
1011 (w, br, sh), 866 (w, br), 729 (s)  $\text{cm}^{-1}$ .

MS (20/70 eV) : m/e (%) = 423 (0.1 [ $\text{M}^+$ ]), 323 (4), 168 (89), 140 (100), 85 (31),  
57 (67).

Microanalysis :  $\text{C}_{23}\text{H}_{37}\text{O}_4\text{NS}$

calc.: 423.2443 for [ $\text{M}^+$ ]

found: 423.2410

**Example 12:**

**Compound 7b**

5 mg (0.009 mmol) of 7-O-acetyl-epothilon are dissolved in 1 ml of methanol, 200  $\mu$ l of an ammoniacal methanol solution (2 mmol  $\text{NH}_3$ /ml methanol) are added and the reaction mixture is stirred at 50°C for two days. To work up, the solvent is removed *in vacuo*. The crude product is purified by preparative layer chromatography (eluant: toluene/methanol, 90:10).

Yield : 3 mg (59%)

R<sub>f</sub> (dichloromethane/methanol, 90:10) : 0.63

IR (film) :  $\nu_{\text{max}}$  = 3441 (m, b, sh), 2946 (s, sh), 1732 (vs), 1600 (w), 1451 (m), 1375 (m), 1246 (s, b, sh), 1013 (m, b, sh)  $\text{cm}^{-1}$ .

UV (methanol) :  $\lambda_{\text{max}}$  (lg  $\epsilon$ ) = 211 (3.75), 247 (3.59) nm.

MS (20/70 eV) : m/e (%) = 567 (1 [ $\text{M}^+$ ]), 465 (4), 422 (7), 388 (5), 194 (5), 182 (7), 168 (65), 164 (17), 140 (100), 97 (10), 71 (22), 43 (27).

Microanalysis :  $\text{C}_{29}\text{H}_{45}\text{O}_8\text{NS}$

calc.: 567.2866 for [ $\text{M}^+$ ]

found: 567.2849

**Example 13:**

50 mg of epothilon A are dissolved in 20  $\mu$ l of dimethyl sulphoxide and diluted with 30 ml of phosphate buffer (pH 7.1, 30 mM). After the addition of 5 mg of pig liver esterase (Boehringer Mannheim), the mixture is stirred for 2 days at 30°C. The mixture is acidified to pH 5 with 2N HCl and the epothilonic acid 7 is extracted with

ethyl acetate. The organic phase is dried with sodium sulphate and concentrated to dryness by evaporation *in vacuo*. Yield 48 mg (96%).

**Example 14:**

48 mg of epothilonic acid 7 are dissolved in 6 ml of abs. THF and, with stirring, 40 µl of triethylamine and 16 µl of 2,4,6-trichlorobenzoyl chloride are added. After 15 minutes, the precipitate is removed by filtration and the filtrate is added dropwise, within a period of 15 minutes, with rapid stirring, to a boiling solution of 20 mg of 4-dimethylaminopyridine in 200 ml of abs. toluene. After a further 10 minutes, the mixture is concentrated by evaporation *in vacuo* and the residue is partitioned between ethyl acetate/citrate buffer (pH 4). After separation by preparative HPLC, the evaporation residue of the organic phase yields 15 mg of epothilon A.

**Example 15:**

**Epothilons C and D as starting materials**

**A. Production strain and culture conditions corresponding to the epothilon basic patent.**

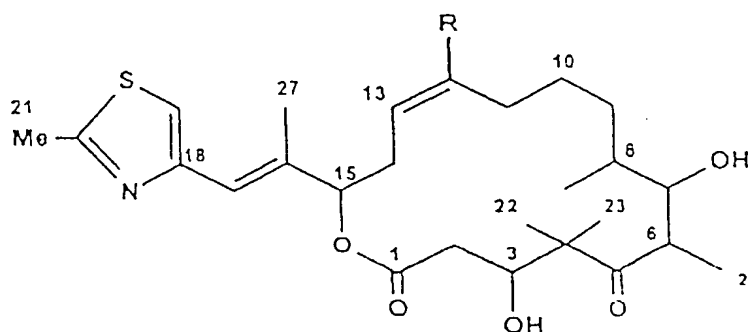
**B. Production using DSM 6773**

75 litres of culture are cultured as described in the basic patent and are used for inoculation into a production fermenter containing 700 litres of production medium consisting of 0.8% starch, 0.2% glucose, 0.2% soya flour, 0.2% yeast extract, 0.1%  $\text{CaCl}_2 \times 2\text{H}_2\text{O}$ , 0.1%  $\text{MgSO}_4 \times 7\text{H}_2\text{O}$ , 8 mg/litre of Fe-EDTA, pH = 7.4 and optionally 15 litres of Amberlite XAD-16 adsorber resin. Fermentation lasts for from 7 to 10 days at 30°C, with aeration with 2 m<sup>3</sup> air/h. The pO<sub>2</sub> is maintained at 30% by regulating the speed.

### C. Isolation

The adsorber resin is separated from the culture using a 0.7 m<sup>2</sup> 100-mesh process filter and is freed of polar impurities by washing with 3 bed volumes of water/methanol 2:1. Elution with 4 bed volumes of methanol yields a crude extract which is concentrated by evaporation *in vacuo* until the aqueous phase occurs. That is then extracted three times with the same volume of ethyl acetate. Concentration of the organic phase by evaporation yields 240 g of crude extract which is partitioned between methanol and heptane in order to separate off lipophilic impurities. From the methanolic phase there are obtained by concentration by evaporation *in vacuo* 180 g of isolate which is fractionated in three portions over Sephadex LH-20 (20 x 100 cm column, 20 ml/min methanol). The epothilons are contained in the fraction which is eluted in the retention time from 240 to 300 minutes and which comprises a total of 72 g. To separate the epothilons, chromatography is carried out in three portions on Lichrosorb RP-18 (15 µm, 10 x 40 cm column, eluant 180 ml/min methanol/water 65:35). After epothilon A and B there are eluted epothilon C at  $R_t = 90-95$  min and epothilon D at  $R_t = 100-110$  min, which are obtained, after concentration by evaporation *in vacuo*, in each case in a yield of 0.3 g of a colourless oil.

### D. Physical properties



Epothilon C     $R = H$

Epothilon D     $R = CH_3$

#### Epothilon C

$C_{26}H_{39}NO_5S$  [477]

ESI-MS : (positive ions) : 478.5 for  $[M+H]^+$

$^1\text{H}$  and  $^{13}\text{C}$ , see NMR table

TLC:  $R_f = 0.82$

TLC aluminium foil 60 F 254 Merck, eluant : dichloromethane/methanol = 9:1

Detection : UV extinction at 254 nm. Spraying with vanillin/sulphuric acid reagent,  
blue-grey coloration on heating to 120°C.

HPLC :  $R_t = 11.5$  min

Column: Nucleosil 100 C-18 7  $\mu\text{m}$ , 125 x 4 mm.

Eluant: methanol/water = 65:35

Flow rate : 1 ml/min

Detection: diode array

#### Epothilon D

$\text{C}_{27}\text{H}_{41}\text{NO}_5\text{S}$  [491]

ESI-MS : (positive ions) : 492.5 for  $[\text{M}+\text{H}]^+$

$^1\text{H}$  and  $^{13}\text{C}$ , see NMR table

TLC :  $R_f = 0.82$

TLC aluminium foil 60 F 254 Merck, eluant : dichloromethane/methanol = 9:1

Detection : UV extinction at 254 nm. Spraying with vanillin/sulphuric acid reagent,  
blue-grey coloration on heating to 120°C.

HPLC :  $R_t = 15.3$  min

Column : Nucleosil 100 C-18 7  $\mu\text{m}$ , 125 x 4 mm

Eluant : methanol/water = 65:35

Flow rate : 1 ml/min

Detection: diode array



Table:  $^1\text{H}$  and  $^{13}\text{C}$  NMR data of epothilon C and epothilon D in  $[\text{D}_6]\text{DMSO}$  at 300 MHz

Epothilon C				Epothilon D		
H atom	$\delta$ (ppm)	C atom	$\delta$ (ppm)	$\delta$ (ppm)	C atom	$\delta$ (ppm)
		1	170.3		1	170.1
2-Ha	2.38	2	38.4	2.35	2	39.0
2-Hb	2.50	3	71.2	2.38	3	70.8
3-H	3.97	4	53.1	4.10	4	53.2
3-OH	5.12	5	217.1	5.08	5	217.4
6-H	3.07	6	45.4	3.11	6	44.4
7-H	3.49	7	75.9	3.48	7	75.5
7-OH	4.46	8	35.4	4.46	8	36.3
8-H	1.34	9	27.6	1.29	9	29.9
9-Ha	1.15	10	30.0	1.14	10	25.9
9-Hb	1.40	11	27.6	1.38	11	31.8*
10-Ha	1.15*	12	124.6	1.14*	12	138.3
10-Hb	1.35*	13	133.1	1.35*	13	120.3
11-Ha	1.90	14	31.1	1.75	14	31.6*
11-Hb	2.18	15	76.3	2.10	15	76.6
12-H	5.38**	16	137.3		16	137.2
13-H	5.44**	17	119.1	5.08	17	119.2
14-Ha	2.35	18	152.1	2.30	18	152.1
14-Hb	2.70	19	117.7	2.65	19	117.7
15-H	5.27	20	164.2	5.29	20	164.3
17-H	6.50	21	18.8	6.51	21	18.9
19-H	7.35	22	20.8	7.35	22	19.7
21-H <sub>3</sub>	2.65	23	22.6	2.65	23	22.5
22-H <sub>3</sub>	0.94	24	16.7	0.90	24	16.4
23-H <sub>3</sub>	1.21	25	18.4	1.19	25	18.4
24-H <sub>3</sub>	1.06	27	14.2	1.07	26	22.9
25-H <sub>3</sub>	0.90			0.91	27	14.1
26-H <sub>3</sub>				1.63		
27-H <sub>3</sub>	2.10			2.11		

\*, \*\* allocation interchangeable

**Example 15:**

**Epothilon A and 12,13-bisepi-epothilon A from epothilon C**

50 mg of epothilon A are dissolved in 1.5 ml of acetone, and 1.5 ml of a 0.07M solution of dimethyldioxirane in acetone are added. After 6 hours' standing at room temperature, concentration by evaporation *in vacuo* is carried out and separation is effected by preparative HPLC on silica gel (eluant: methyl tert-butyl ether/petroleum ether/methanol 33:66:1).

Yield:

25 mg of epothilon A,  $R_t = 3.5$  min (analyt. HPLC, 7  $\mu$ m, 4 x 250 mm column, eluant see above, flow rate 1.5 ml/min

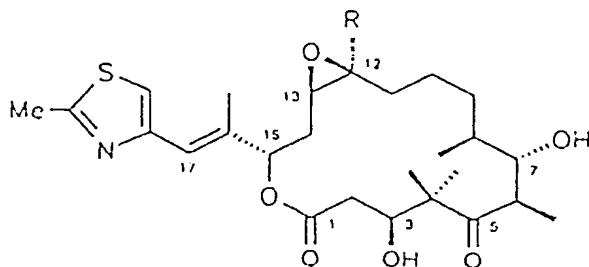
and

20 mg of 12,13-bisepi-epothilon A,  $R_t = 3.7$  min, ESI-MS (pos. ions)

$m/z = 494 [M+H]^+$

$^1\text{H-NMR}$  in  $[\text{D}_4]$  methanol, selected signals:

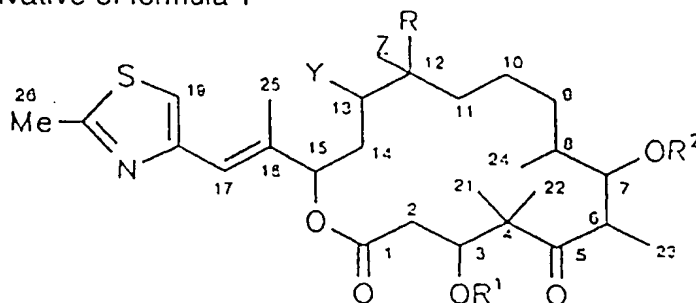
$\delta = 4.32$  (3-H), 3.79 (7-H), 3.06 (12-H),  
3.16 (13-H), 5.54 (15-H), 6.69 (17-H), 1.20  
(22-H), 1.45 (23-H).



12,13-bisepi-epothilon A  $R = \text{H}$

## Patent Claims

1. Epothilon derivative of formula 1

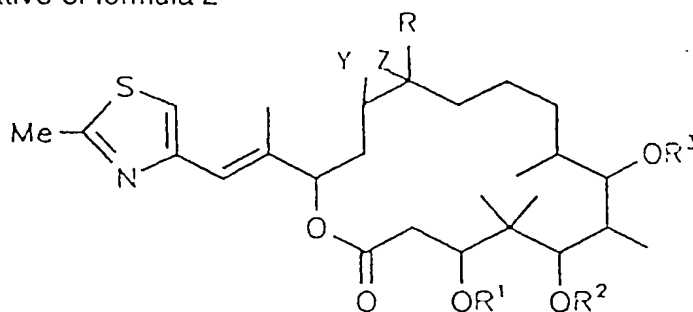


1

wherein

R = H, C<sub>1-4</sub>alkyl; R<sup>1</sup>, R<sup>2</sup> = H, C<sub>1-6</sub>alkyl, C<sub>1-6</sub>acyl, benzoyl, C<sub>1-4</sub>trialkylsilyl, benzyl, phenyl, or benzyl or phenyl each substituted by C<sub>1-6</sub>alkoxy, C<sub>6</sub>alkyl, hydroxy or by halogen; and the alkyl and acyl groups contained in the radicals are straight-chain or branched radicals, and Y and Z are either identical or different and each represents hydrogen, halogen, pseudohalogen, OH, O-(C<sub>1-6</sub>)acyl, O-(C<sub>1-6</sub>)alkyl or O-benzoyl, or together form the O atom of an epoxy group or one of the C-C bonds of a C=C double bond, epothilon A and B being excluded.

2. Epothilon derivative of formula 2



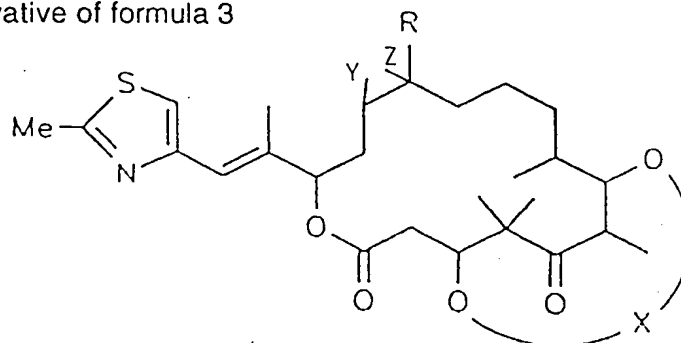
2

wherein

R = H, C<sub>1-4</sub>alkyl; R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup> = H, C<sub>1-6</sub>alkyl, C<sub>1-6</sub>acyl, benzoyl, C<sub>1-4</sub>trialkylsilyl, benzyl, phenyl, or benzyl or phenyl each substituted by C<sub>1-6</sub>alkoxy, C<sub>6</sub>alkyl, hydroxy or by

halogen; the alkyl and acyl groups contained in the radicals are straight-chain or branched radicals; and Y and Z are as defined according to claim 1.

3. Epothilone derivative of formula 3

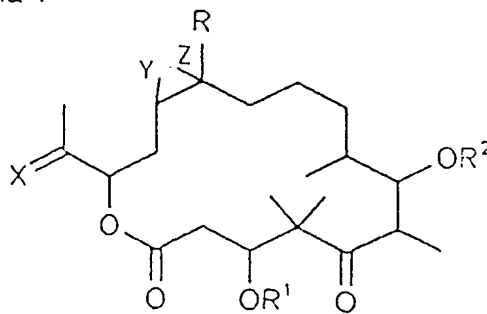


3

wherein

R = H, C<sub>1-4</sub>alkyl; R<sup>1</sup>, R<sup>2</sup> = H, C<sub>1-6</sub>alkyl, C<sub>1-6</sub>acyl, benzoyl, C<sub>1-4</sub>trialkylsilyl, benzyl, phenyl, or benzyl or phenyl each substituted by C<sub>1-6</sub>alkoxy, C<sub>6</sub>alkyl, hydroxy or by halogen; the alkyl and acyl groups contained in the radicals are straight-chain or branched radicals, and X generally represents -C(O)-, -C(S)-, -S(O)-, -CR<sup>1</sup>R<sup>2</sup>- or -SiR<sub>2</sub>-, wherein R, R<sup>1</sup> and R<sup>2</sup> are as defined above and R<sup>1</sup> and R<sup>2</sup> may also together form an alkylene group having from 2 to 6 carbon atoms; and Y and Z are as defined according to claim 1.

4. Epothilone derivative of formula 4



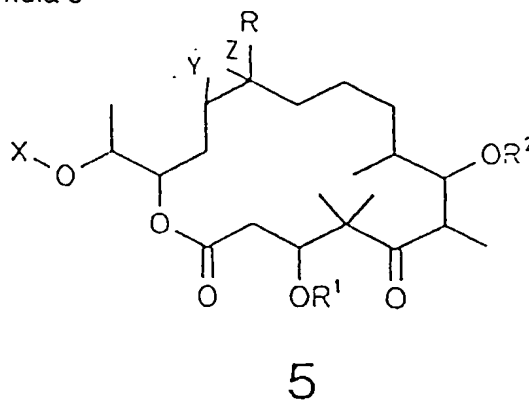
4

wherein

R = H, C<sub>1-4</sub>alkyl; R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup> = H, C<sub>1-6</sub>alkyl, C<sub>1-6</sub>acyl, benzoyl, C<sub>1-4</sub>trialkylsilyl, benzyl, phenyl, or benzyl or phenyl each substituted by C<sub>1-6</sub>alkoxy, C<sub>6</sub>alkyl, hydroxy or by halogen; the alkyl and acyl groups contained in the radicals are straight-chain or

branched radicals, X represents oxygen,  $\text{NOR}^3$ ,  $\text{N-NR}^4\text{R}^5$  or  $\text{N-NHCONR}^4\text{R}^5$ , wherein the radicals  $\text{R}^3$  to  $\text{R}^5$  are as defined above and  $\text{R}^4$  and  $\text{R}^5$  may also together form an alkylene group having from 2 to 6 carbon atoms; and Y and Z are as defined according to claim 1.

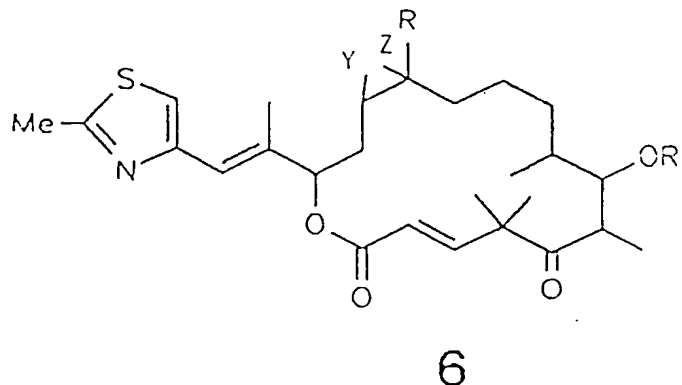
5. Epothilon derivative of formula 5



wherein

$\text{R} = \text{H}$ ,  $\text{C}_{1-4}\text{alkyl}$ ;  $\text{R}^1$ ,  $\text{R}^2 = \text{H}$ ,  $\text{C}_{1-6}\text{alkyl}$ ,  $\text{C}_{1-6}\text{acyl}$ , benzoyl,  $\text{C}_{1-4}\text{trialkylsilyl}$ , benzyl, phenyl, or benzyl or phenyl each substituted by  $\text{C}_{1-6}\text{alkoxy}$ ,  $\text{C}_6\text{alkyl}$ , hydroxy or by halogen; the alkyl and acyl groups contained in the radicals are straight-chain or branched radicals, and X represents hydrogen,  $\text{C}_{1-18}\text{alkyl}$ ,  $\text{C}_{1-18}\text{acyl}$ , benzyl, benzoyl or cinnamoyl, and Y and Z are as defined according to claim 1.

6. Epothilon derivative of formula 6

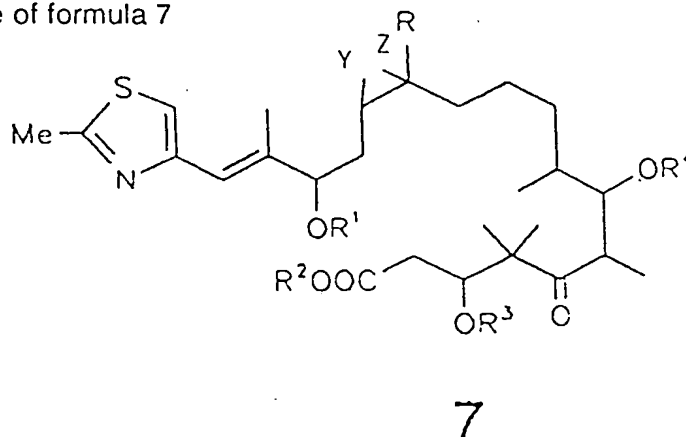


wherein

$\text{R} = \text{H}$ ,  $\text{C}_{1-4}\text{alkyl}$  and  $\text{R}^1 = \text{H}$ ,  $\text{C}_{1-6}\text{alkyl}$ ,  $\text{C}_{1-6}\text{acyl}$ , benzoyl,  $\text{C}_{1-4}\text{trialkylsilyl}$ , benzyl, phenyl, or benzyl or phenyl each substituted by  $\text{C}_{1-6}\text{alkoxy}$ ,  $\text{C}_6\text{alkyl}$ , hydroxy or by halogen; the

alkyl and acyl groups contained in the radicals are straight-chain or branched radicals; and Y and Z are as defined according to claim 1.

7. Epothilon derivative of formula 7



wherein

R = H, C<sub>1-4</sub>alkyl and R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup> = H, C<sub>1-6</sub>alkyl, C<sub>1-6</sub>acyl, benzoyl, C<sub>1-4</sub>trialkylsilyl, benzyl, phenyl, or benzyl or phenyl each substituted by C<sub>1-6</sub>alkoxy, C<sub>6</sub>alkyl, hydroxy or by halogen; the alkyl and acyl groups contained in the radicals are straight-chain or branched radicals; and Y and Z are as defined according to claim 1.

8. Process for the preparation of an epothilon derivative of formula 7 according to claim 7, characterised in that epothilon A, epothilon B, a 3-OH-protected derivative thereof or a 7-OH-protected derivative thereof is

- (a) enzymatically hydrolysed, especially with an esterase or lipase, or
- (b) hydrolysed in an alkaline medium, especially with sodium hydroxide in a methanol/water mixture,

and the epothilon derivative of formula 7 is obtained and isolated.

9. Process for the preparation of an epothilon derivative of formula 2 according to claim 2, characterised in that an epothilon derivative of formula 7 according to claim 7 or in the form of the product of the process according to claim 8 is converted

- (a) according to the Yamaguchi method, or
- (b) according to the Corey method, or
- (c) according to the Kellogg method

to form the epothilon derivative of formula 2 and that conversion product is isolated.

10. Process for the preparation of epothilon A and/or 12,13-bisepi-epothilon A, characterised in that epothilon C is epoxidised, especially with dimethyldioxirane or with a peracid.

11. Process for the preparation of epothilon B and/or 12,13-bisepi-epothilon B, characterised in that epothilon D is epoxidised, especially with dimethyldioxirane or with a peracid.

12. Composition for plant protection in agriculture and forestry and/or in horticulture, consisting of one or more of the compounds according to any one of the preceding claims or of one or more of those compounds together with one or more customary carrier(s) and/or diluent(s).

13. Therapeutic composition, especially for use as a cytostatic agent, consisting of one or more of the compounds according to one or more of claims 1 to 7 or of one or more of the compounds according to one or more of claims 1 to 7 together with one or more customary carrier(s) and/or diluent(s).

### Abstract

The present invention relates to epothilon derivatives and to their use.